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GROUP

## CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

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PRIORITY DATE

No. OF CLAIMS

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#### LINER EXPANDER

This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the losding on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lover bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

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The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft ld.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein  $P_{\mathbf{c}}$  is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

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approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1. A device for expanding a metallic liner inside a conduit which 1 device comprises a shaft element, an expanding die member attached to said 2 shaft element, said die member comprising a movable liner-forming member 3 positioned on said shaft and being radially movable in respect thereof to h 5 contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member 6 from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against 9 10 said liner by a substantially constant force.
- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said 2 conduit to expand said liner: a cylindrical shaft element, an expanding die 3 member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to 5 6 contact said liner, a cone member slidably positioned on said shaft between 7 said shaft and said arm members to urge said arm members outwardly from said 8 shaft, and a constant force spring member positioned on said shaft to contact 9 said cone member and to maintain said cone member in contact with said arm 10 members, whereby said arm members are urged outwardly by a substantially 11 constant force.
  - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 4. The device of Claim 3 wherein said compression means comprises a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

  2 sleeve-like element connected to said movable bearing plate member and

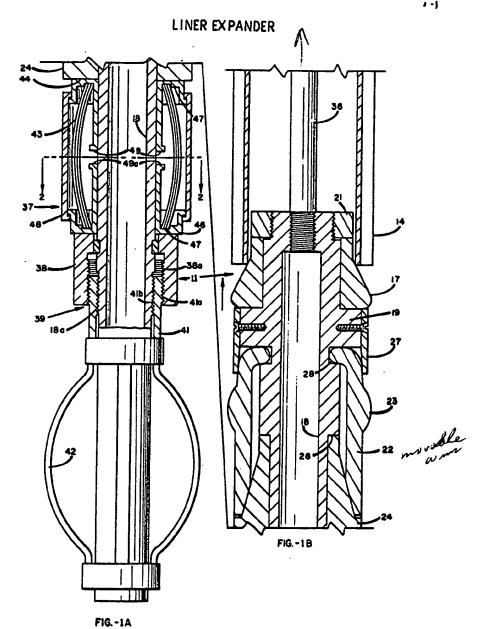
  3 slidably positioned on said shaft and a member connected to said shaft to

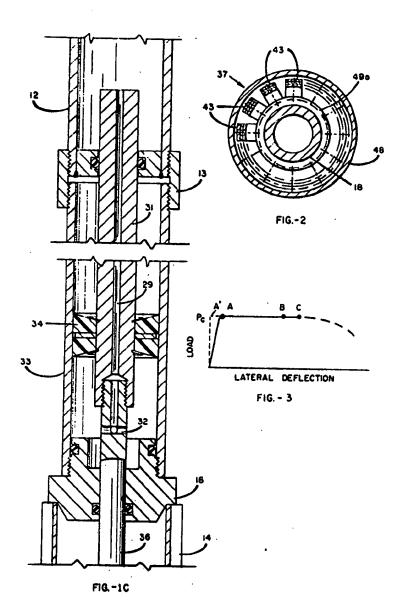
  4 limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
- 1 7. A device for installing an expanded metallic liner in a conduit 2 which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably 6 positioned on said shaft between said shaft and said arm members to urge said 7 arm members outwardly from said shaft; a plurality of slender columns, each 8 having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lover bearing plate member, 9 10 each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members 11 12 and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply 13 14 a buckling load to said columns; said shoulder being engageable with the 15 limiting sleeve connected to said lower bearing plate member, whereby the 16 axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members . 17 18 outwardly with a substantially constant force.

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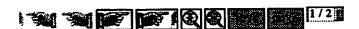
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3. The favoire of Claim 2 shareds said constant force opening contert congrisce a planning of column disposed account said shaft, a first bearing plate number, such of said bearing plate number, such of said bearing plate numbers contacting opposite coins of said columns, at least one of said tearing plate numbers being movebly positioned on said shaft and being in contact with said come number, stop moves connected to said start to limit the axial trivial of said number, stop power connected to said start; and compression mesons for valuationing a lateral deploytion in said columns.

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- A. The certae of Chain 3 wherein said compression comm comprises a differential mover expending and againg number and said shaft.
- 5. The device of Claim 3 wherein said atop mean comprises a ent connected to mid wowhle bearing plate number and strainly positioned on said shaft and a souther commuted to said shaft to times the transit of sale places. Like places.
- 6. The dovice of thate 3 were's soil columns have a sectingular cross-sorbins, the width being greater than the thickness, and having the stars from success to the dissource of mid shaft.
- 7. A device for installing at expended untallic liner to a contest which comprises a sylimitrical short almostly on asympting the system meanted On said shall, said the senter comprising a planning of ere somers disposed formulally around the outside of sold shaft and being plustable detmaily therefrom to equient the liner; a scalest expending states slidely . By outstandly from suid shaft; a plantality of element columns, each besing a long restangular areas-striken and disposed stransparentially about seld chaft; an upper bearing plats sember and a lower bearing plats scatter, such alidably positioned on said shaft and contacting opposite onds of said my limiting alsows ubtacked to each of still bearing plate numbers and alidably positioned as said shafts a shoulder number on mad shafts a differential sever element connecting sold shoulder and sold stack to apply a landiting load to said enimous said thouldest being engageable with the 15. Limiting steams summered to each loan bearing plate melon, whereby the exist travel of said bearing plate members is limited; said column resolute 17 branchitting their burning lood to each arm restors to tryp said and grobers cotwordly with a substantially constant force.

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As styled of the present invention is a florine for applying a conrient force to an expending die or etter sixilar expension so that a presolution invitum force is assisted against a verb place. Soother shipsh is an Improved expending tool for installing mobilis liners is a conduit, which expending tool one agaly so greater them a predetermined force to the liner being installed in the equality. Still another object of the invention is an economical and anally folcionist assistant force opting device. I further object to a regard, compute-countie expending tool contaging such a spring device. These and other objects of the invention of the invention.

In accordance with the present terestion there is provided a constrat force spring device which comprises a body member, an elongated solumn element adjacent said body member, bearing plate numbers contecting the two costs of said column at least one of said bearing plate numbers being longituitiabily servely in respect of the other and stop seems as said body mimber to limit the deflection of said column element to provide parameter deformabing of said column element open the application of a compressive load thereto. In our extensions of the invention, the foregoing constant force spring device to explayed in a tool for supersing a satallic liner inside a substite, said constant force spring device being positioned on said tool to ways an expecting tie sealer against the liner being installed in the conduct by a substantially constant force.

My invention will be better enterated by returnment to the following description and the accompanying drawings wherein:

Piggres 14, 18 and 10, taken together, conviltute a pertial sectional view of a preferred enhalizant of a liner expending tool according to the recent terminisms and





Figure 2 is a sestional view of the apparatus of Figure 1A taken 4t

Figure 3 is a typical plot of applied look versus believiton for the constant force spring device of the investion.

Referring to the drawings, Figure 14 is the bottom portion of a liner expending book for one in installing a motable liner is a well, while sents the upper section of the teal. The expending took il is abtembed to stantant wall taking 18 by ampling 15 out, typically, may be lowered from the surface through a well ensing (not shown) to a point in the swring at which it in sectral to invisit a metallic liner. Before inserting the test into the well, an alongsted vertically corrupted liner 10 fabricated from mild steel, or other suitable malachie meterial, in placed on the tool. The corrupted liner is section in position by centart at its upper ent with a cylindrical alter number 16 and, at the lower and by contact with a first-stage expansiing die 17 in the form of a trumontal circular core which serves as a firstfixedly obtained to a controlly located, elemental sylintrical hollow shaft lô which forms a parties of the body of the tool. As shows, the expending the 17 is half in place between a lawer shoulder 19 and collar 21 threaded outs the . A plurality of morphic arms 27, preferably provided with undeardly salargek portions 85 mar the top; wis disposed in the form of a syllutur o a cohelectially cylindrical chaps. The are conhere H2 are pirotally etteched to the sheft so as to be movehic subsatily into the sheft by a tapered expending member 26 slidebly quelifored on the sheft to corve as a second-stage oler. The sections of the meabor is, as shown, moved upwardly along the chart to engage with the erms and more then outserfly. Advantageously, the vertices of the ease 52 and the outside carries of expending member 25 form setting sentious, typically categoral is shape. The expension of the arm to is controlled by the position of the master 26 raich moves superally





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In operation, the liner setting tool is assembled at the surface, so described shows, and a glass circle semmeted with a restance material may be at the corrugated take to form the liner. The assembly is lovered into the wall as the location at which the liner is to be set. A liquid, such so oil, is then pusped under presence does the well tubing sad flore through nagemy 29 provided to golished roi 31, through parts 55 and into epitaetad to the upper and of the aboulder lo. Upon the application of find pressure to the cylinder, the pistes 34 secords to polished red 31 moved specially in sylinder 33. As shows, rot 36 cornects polithed rot 31 and shaft 15 spot sideh is mounted the Eirst-stage expending siz 17. Then the piston \$4 orthy through the symmetry 33 the expending die 17 sed, the secondstage die 22 ero draws upwardly into the corrugated liner 16 and "iron out" the corregations in the liner, so that the expected liner may contact the tamile well of the cesting in which it is being installed. Positiosof on the shaft below the expending menter th is a constant turns spring number 37 which is employed to targe the expending number squiest the expluding stars 22 with a substantially sensiant force. The force exacted against the are needers being substantially monetant, the force transmitted through the arm numbers to the lists and to the during will be substantially exceeded as that either skidding of the tool in the casing or regime of the casing is precluded. Of course, the three profiles by the spring mester is preselected so that the frictional



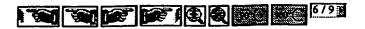


forces between the tool and the liner and the preserve emerted spring the oneing are eminimized at predefication sufe levels. The complete force spring number ensures that the contact preserve between the liner forming portion 20 of the sous 22 is great enough to provide the derived deformation of the stat-

The equators force spring conter 77 is alignity nominal on the shart 18 ced hald between the expending alongst 26 ced a sylintrical inver chemidal member 18 ferming a portion of a distinguishal occur alongst 39 which betweents the hoding on spring number 27 to shart member 18. The distinguishal occur alongst comprises about member 18 on the cetrids of units are only not transfelled. The lower abouter number 18 provided with famile threads 35, and thinkle number 18, provided with threads the out 180 provided with threads with the shart and the choider. The two cete of threads are number, such as square, andifful equare, or done through, to withstand very high lands and differ in pitch so that shoulder 35 is agreed appearing on the shart 18 when the shart is required relative to thinkle 11. The choider 36 is necessar to the shart 18 by splines 43 so that at can alider inequality, but it is not true to review on the shart. Finally arisabed to the lower out of the thinkle is a striction number, such as low aprings 48, a aptraulically equated friction past, or other much device for frietlymbly compaging with the incide well of the conjuit to occure the thinkle against touched threads 36a to the same as that of the shart threads 18a, e.g. right-hand threads. Sha to the same as that of the shart threads 18a, e.g. right-hand threads 35a, with the pitch, or land, or threads 18a is slightly greater than think of threads 35a, with the pitch, or land, or threads 18a is slightly greater than think or threads 35a, with the pitch relate things along to unity. In this summer, clock-vine resolution of the chart relative to the thinkle summs shoulder square 18 to advance upwerd allightly and a congression load is convicted upwardly on agains alamned 37 to cause welling. For example, one retief and therefore threads as a short approximately 1.7-inch outside dismeter and tive and threads incide and therefore.



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#### 736288

Constant force spring element 37 comprises unions element \$5, structagementy constitutes of a plurality of alongsissi solumes disposed around shall id. Upper bearing plate confect \$\$ is in contact with the apper unds of the column and is although positioned on shall if to trumsait the force of the spring longitudinally against the bottom and of expenden contact \$\$\$. Lower bearing plate number \$\$\$ contact the lower and of the column and is cover appearing along the small by leadinal movement of lossy smallder \$\$\$\$ on a result of revolving differential source almost \$9\$. Greaves \$7\$ are provided in such or the bearing plates, to form on upper case and a lower mose, inche which the case of the column are inserted. These groups may be compact to conclude foreign matter from the spring mechanics and to protect the complete to amplice foreign matter from the spring mechanics and to protect

A notes for limiting the deflection of the columns to required. Although the column element furnitions in a bushled scenition, application of . commutes load thereto would sense total failure or repture of the re, a pair of stope by and bya are provided for this purpose. us, the stope ere rigidly commetted to the bearing plates, and, in effort comprise upper and lower limiting electes positioned on the shaft to alide longitudinally thereon. The under of the stops may nove toward, or same from, each other so the look in the spring number wortes. Lover slower high ected from moding dams by hower shoulder 50 ecomocied to the obert 18. on the sade is much as to limit the longitudinal ral of the bearing plate mesters as they more together to prevent perme rties of the column alessest by. Waxious alternative masse for preventage to the colone element may also be employed. For example, plas or rings sometal on the obest may serve as stops, or the cover 48 provided with exitable connections may be suplayed for this purpose to limit langitudies? and/or lateral deflection of columns.

The columns of the calmen vignest 43 may be arranged around the chart 18, which as shown here fures a portion of the body of the spring favour, with make of the columns fitted in the prope 57. The solumns may be

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rated closely together as shore, or only he spaced around the state, with representative used between them to meisteds the desired spacing. The resolute of solutes supleyed will depend upon column characteristics and the smintles of construction. For example, the eleminatery ratio of the column may be varied widnly, say the column made may be recent, flat, flund or himself. The preferred construction is a thin, element column with resolute ands, from to move within the process chapat to the column with resolute ands, from to move within the process chapat to the column with resolute and an alley study only to anticipatively supplyed for the column made. Materials which may be anticipated because attained extends and an alley study, such direction becomes, buryline support, the high which allows and other miniture materials providing estimated extended properties. Typically, the individual columns are of long restampular cross-meeties, with the wider face of the unitume for more all the almost are of the about the attained consensation lossing, the columns buckle, and band about the acts having the loast commet of inertia, e.g., outwartly may from the about 18.

For armshr, a group of columns 0.164-inch thick by 0.836-inch wife by 10.626-inches long, with the ends roussed, were febriowich from A.f.S.I him onesel, quantitied and draws at 775°F. Buth column was found to require a critical sequescentian loading of 350 pounds in order to bunkle the addison.

After bunkling, the columns were found to have a wary first spring characteristic, see shown in Figure 3, wherein Fo is the critical bunkling lead and point of represents the load and deflection at which the stress in the externs fibers of this spring characteristic surve is described by cores 04'ABO. Actually, this cores is described by cores 04'ABO. Actually, this cores is described by OABO due to friction in the system. Potota A and a represent typical working limits, which, of course, say he varied according to the application for which the spring is designed. For example, where a large masher of flexing cycles are not soutquieted, a working stress just below the yield point may be used, while with a great suster of flexines, the working stress may be held to less than the endurance limit of the material of sonstress time. In the algore-manifoced tests, the lateral intrinction was limited to

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equinciantely one fuch, at which the longitudinal deflortion was approximately 0.225 inches. From more deflortion to the assumen deflortion, the \$50-pound loading was found to be substantially constant.

In earther test a spring device was built, as down, employing 80 columns, each having a critical bushling load of 1250 younds. The internal definition was limited between 0 and about 1.00 inches by empropriately positioning the steps. Once compressional leading, the spring element buckled at scatternally 25,000 pounds and from a lengthetical defication of 0.05 inches (bushling) to stook 0.15 inches the land remarked substantially at 25,000

Or essures, in designing a spring element an above it in advantagements of detain the greatest possible value of longitudinal defination for specified values of laboral deflection and exitical bushling load, while unintending the atrees level in the columns at a rate level. The preferred columns, therefore, are laminated, as shown in Figures 13 and 2, with militals flat methods while on seath columns.

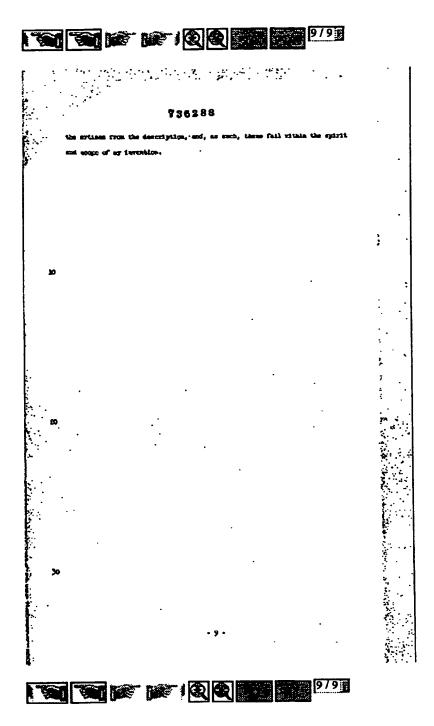
Do the operation of the shows capaciting tool for switing a liner in well excises, the medo-up tool is lowered into the well as mentioned shows, with the area 22 in the reteneted position. Then the tool is at the desired level, the sell taking is revolved. The fristion number of capacity with the wall of the manny and revenue thinkle is from revolving. With several revolutions of the taking, lower shoulder 35 is novel meantly by differential entre 39 to bushle opening element 37 thick has a predeferminal existent bushling load. This last is transitivel squarely against the lower sak of expendent 36, and the tapered surface is engaged with the tapered surface on the Lables of the error 22 to urgs the base extractly with a substantially constant furce proportional to the critical bushling load of the spring element. Exceptantly, the expending tool is passed through the liner to expend it to the caping in the sensor described be/stabe/ore.

the foregoing description of a preferred embeliant of my invention.

Let the purpose of examplification. It will be understood that various medifications in the descript of excellent will become apparent to

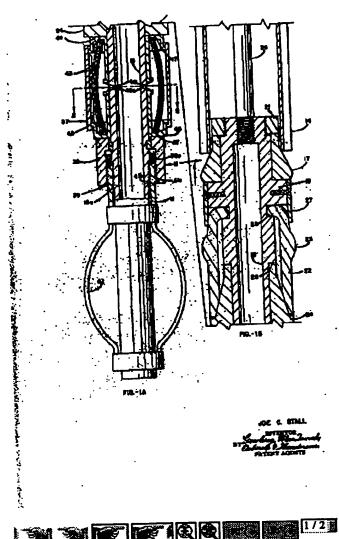
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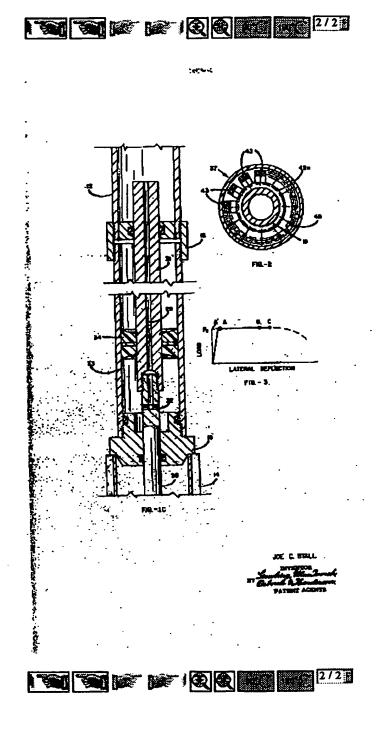
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